INTERNATIONAL
SOIL AND WATER
CONSERVATION RESEARCH

Comparison of erosion and erosion control works in Macedonia, Serbia and Bulgaria

Ivan Blinkov[1], Stanimir Kostadinov[2], and Ivan Ts. Marinov[3]

Abstract

While soils are as essential to human society as air and water, soil degradation has not received nearly as much attention as the threats to these other elements. On the map of water erosion of Europe, Southern Europe is red "colored". Erosion in the Balkan countries, through both on and offsite effects is a major cause of soil and water degradation.

This paper compares erosion control works in several countries from the Balkan region (Macedonia, Serbia, and Bulgaria). The basis for comparative analyses was various country reports as well as available published papers. Quantitative method-text analyze method was used for these study.

Natural conditions in the Balkan countries contribute to the appearance of various erosion forms and the intensity of the erosion processes. Over the history of these countries, people who settled this region used the available natural resources to fill their needs (tree cutting, incorrect plugging, overgrazing), which contributed to soil erosion. Organized erosion control works in the Balkans started in the beginning of the 20^{th} century (1905 in Bulgaria). The highest intensity of erosion control works were carried out during the period 1945 – 1990. Various erosion control works were launched. Bulgaria had a large anti-erosion afforestation, almost 1 million ha. Bulgaria's ecological river restoration approach has been in use for almost 50 years. Serbia contributed significant erosion and torrent control works on hilly agricultural areas. Specific screen barrages and afforestation on extremely dry areas are characteristic in Macedonia. A common characteristic for all countries is a high decrease in erosion control works in the last 20 years.

Key Words: Erosion, Erosion control works, Balkan

1 Introduction

Soil erosion is a natural process, occurring over geological time. Most concerns about erosion are related to accelerated erosion, where the natural rate has been significantly increased by human action (Fig. 1). Slope sediment transport processes are of two very broad types, first the weathering and second the transport of the regolith. Within each of these types, there are a number of separate processes, which may be classified by their particular mechanisms into groups, although many of these processes occur in combination. Soil erosion is regarded as the major and most widespread form of soil degradation, and as such, poses severe limitations to sustainable agricultural land use. Soil can be eroded away by wind and water. High winds can blow away loose soils from flat or hilly terrain. Erosion

[1] Prof., Dr., Ss Cyril and Methodius University, Faculty of Forestry, Skopje, R Macedonia. E-mail: vanblinkov@yahoo.com
[2] Prof., Dr., University of Belgrade, Faculty of Forestry, Serbia. E-mail: stanimir.kostadinov@sfb.bg.ac.rs
[3] Prof., DSc, Forest Research Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria. E-mail: marinovbg02@yahoo.com

by water occurs due to the energy of water as it falls to earth and flows over the surface. Most slope processes are greatly assisted by the presence of water, which helps chemical reactions, makes masses slide more easily, carries debris as it flows and supports the growth of plants and animals. For both weathering and transport, the processes can conveniently be distinguished as chemical, physical and biological (Gobin et al., 2002). Erosion damages are classified in 2 basic groups:

(1) "on-site" damages (loss of topsoil and nutrients, disturbance of the hydrological regime, landscape changes) and

(2) "off-site" damages [flash (torrential) flooding, siltation of reservoirs and land in the downstream sections, soil halomorphism, chemical pollution of water with pesticides, fertilizers, and other pollutants connected to the suspended sediment that deposited in the downstream sections and reservoirs].

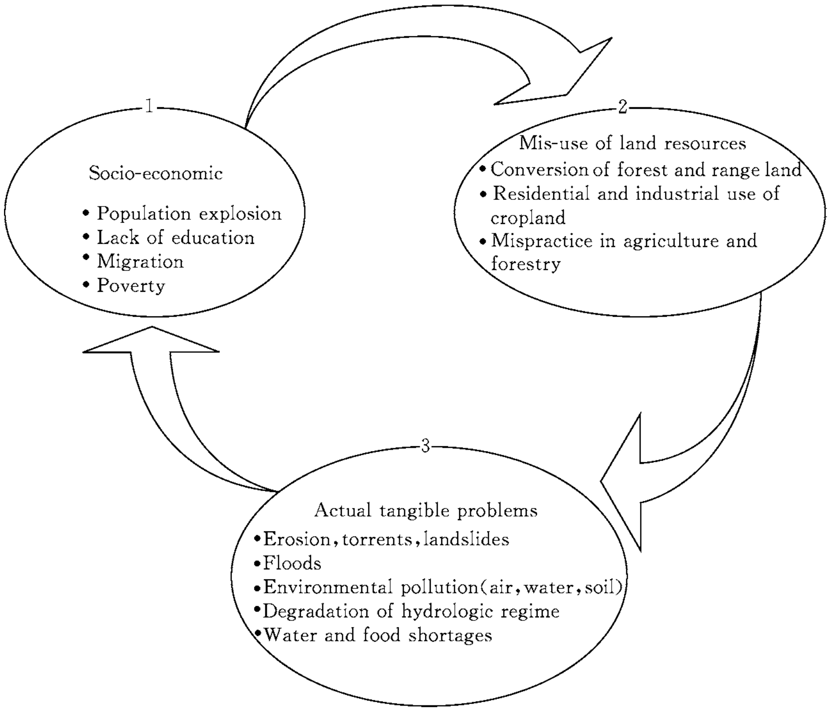


Fig. 1 Interconnectivity of the groups of factors active in degradation of watershed resources in a vicious circle (ÖzyuvacÚet al.)

Water erosion is the most widespread problem of land degradation in Europe. The European Council report produced through the GLASOD data method (Oldeman et al., 1991) enables an overview of land degradation processes in Europe. The South and Southeast region of Europe is significantly prone to water erosion. In parts of the region, erosion has reached a stage of irreversibility and in some places erosion has practically ceased because there is no soil left. With a very slow rate of soil formation, any soil loss of more than 1 t ha^{-1} yr^{-1} can be considered as irreversible within a time span of 50 – 100 years. Losses of 20 to 40 t ha^{-1} in individual storms, that may happen once every few years, are measured regularly in Europe with losses of more than 100 t ha^{-1} in extreme events (Morgan, 1992). It may take some time before the effects of such erosion become noticeable, especially in areas with the deepest and most fertile soils or on heavily fertilized land. However, this is all the more dangerous because, once the effects have become obvious, it is usually too late to do anything about it.

The **erosion control concept** depends on:

—status, role and importance of the object;

—natural (ecological) characteristics generally and partially;

—erosion intensity and erosion forms on the slopes and into the drainage network;

—state and functionality of existing biological alternatives (silvicultural and agro-meliorative) measures, hydraulic and other measures and activities;

—soc-economic characteristics of the area and region.

Erosion control concept, depends on a scale of activity, could be understood as: single (on a small field) or on a watershed scale. A single concept is in use just to solve a single problem especially to minimize any single on-site effect (raindrop erosion, erosion from an agricultural parcel, erosion on construction sites etc.). On a scale of a watershed, erosion control is a part of a whole watershed management planning.

Erosion control measures are classified in the following groups: technical-ameliorative measures; biological-ameliorative measures (silvicultural and agro-meliorative); hydraulic structures; administrative measures and educative measures (Petkovic et al., 1999).

The purposes of technical ameliorative works are: reducing surface water runoff, storing water, reducing erosion on hills, enabling preconditions for biological works (afforestation and grassing as well as agricultural production) on steep slopes, rehabilitation of small gullies etc. In the group of technical-ameliorative works are contour ditches, contour walls (made by various materials), furrows and terraces (various dimensions, forms etc.), single and double wattles, fascines and gabions. These structures could be constructed of materials such as soil, stone, wood, and concrete. The choice of material, form, and dimension should be defined with detailed final designs. Usually in the areas where there is a large quantity of stone, stone structures or gabion structures are recommended. In other areas wood structures or wattles of fascines could be used. During the process of preparing a final design attention should be given to selection of species for planting (drilling), selection of planting (drilling) season, selection of appropriate techniques and approaches for planting (drilling), and selection of the method for land treatment and maintenance of the new plantation etc. Species that enable the fastest and best protection from erosion in the soil conditions of the location have an advantage in a process of selection. Domestic species should be selected in advance. Usually, nature shows the most appropriate species because the present species show their adjustment to various conditions. The characteristics of the species are very important. Species that tend to be in contact with the ground are recommended for steep slopes, especially on road slopes. Productive capacities of the species are secondary in the case of erosion control. In closed areas around reservoirs, the horticultural value of planted species is important. For silviluctural works in extreme locations, species should have wide ecological valence.

The selection of land treatment depends on the needed effects on the soil, water, and erosion. Maintenance of the plantations should be in accordance with their erosion control characters, the habitat conditions, as well as the current legislation. On rocky terrains setting turfs is a common measure employed.

All hydraulic construction: check dams, cascades, thresholds combined with longitudinal construction, dikes, and channels have multiple roles: reducing fluvial erosion and rehabilitation of previous damages, stream bank stabilization, improvement of the water regime, retention of large quantities of sediment for stabilization of landslides. On slopes where there are rock falls, appropriate retardation walls made by gabions or protective wire should be used.

2 Aims, objectives and methods

The main aim of this paper is to present specific erosion control measures and structures used in Macedonia, Bulgaria and Serbia as well as to show their effects.

The objectives of this study are:

—to present the current erosion intensity;

—to analyze and present a historical overview of erosion control in the different countries;

—to describe the most specific erosion control measures and structures in each country;

—to evaluate the effectiveness of the various erosion control measures.

Qualitative method-text analyze method was used in this study. The basis for the comparative analyses were the results of significant studies, country reports related to soil erosion by country and available published papers.

3 Study areas characteristics

The study area was located on the Balkan Peninsula. It encompasses the territory of Macedonia (MKD), Serbia (SR) and Bulgaria (BG).

All three groups of erosion factors – energy, resistance and protection (Morgan, 1992) promote soil erosion in the study area. The energy group includes the ability of rainfall and runoff to cause erosion. The relief in the southern part of Serbia is characterized by relatively steep slopes, which directly influences the energy of the erosive agents. About 80% of the territory of RM belongs to hilly and hilly-mountainous and mountainous regions where slopes are very steep. A significant part of Bulgaria also belongs to the mountain region (see Fig. 2).

Considering the resistance factors, the significant erodibility of the soil and geological substrata should be discussed. The geological structure of the major part of the area consists of rocks of high erodibility (conglomerates, schists, etc.) which contribute to the denudation process. Resistant rocks (granites, andezites, etc.) are present in a smaller area of this region.

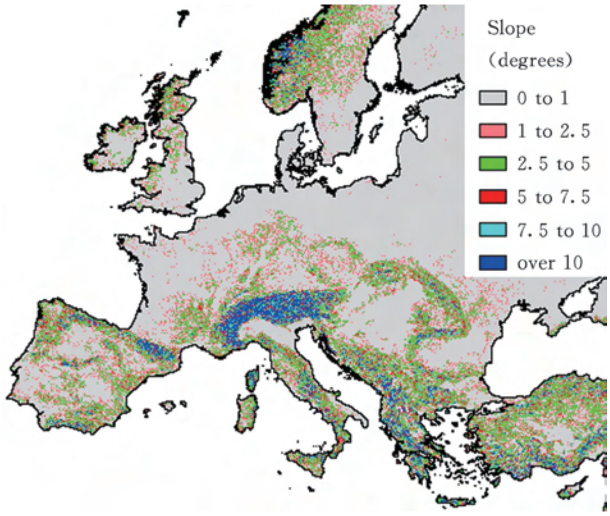


Fig. 2 Slope distribution in Europe

The protection group of erosion factors is related to the population density and land use. The average population density in Serbia is moderate – about 100 inhabitants per km^2, 87 inhabitants per km^2 in Macedonia and 67 in Bulgaria. During its history, this region was permanently settled. Inadequate land treatment and intensive cutting of forests contributed to the high intensity of soil erosion. During the Ottoman Empire period, forest was proclaimed "res nullius", meaning "nobody is the owner of the forest and everybody can cut for filling their own needs". As a result, much of the region was converted from forest to bare land, which rapidly increased soil erosion and torrential flows.

Because of the natural resource and socioeconomic conditions, this region is highly vulnerable to erosion. According to the European Environment Agency (1995), Macedonia, together with Albania, Serbia and Bosnia is the so-called "red zone" of water erosion in Europe.

4 Results

4.1 *Erosion intensity*

The EPM (Erosion Potential Method) is the most comprehensive erosion risk assessment method (ERAM) for meeting watershed management needs. It is an empirical model that estimates the quantity and quality of eroded sediment. EPM gives solution to almost all tasks associated with ERAM, including the evaluations of that depend on scale, that depend on sector or that depend on erosion types (Blinkov and Kostadinov, 2010). For the Balkan territory, the EPM method is the most appropriate for the hilly-mountain and mountain regions (Macedonia, Serbia, Bosnia, Montenegro) (Blinkov & Kostadinov, 2010).

Blinkov and Kostadinov (2010) also found that the use of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) for agricultural areas in the Balkans (hilly and valley) was limited because of the absence of data.

However, various methodologies are used for erosion mapping. While in Macedonia and Serbia the Erosion Potential Model by Gavrilović (1972) is in use, Bulgaria uses the USLE methodology. Data and maps between countries could be compared if data were converted from t ha^{-1} to m^3 km^{-2}.

4.1.1 Erosion intensity in Macedonia

According to the Erosion map of Macedonia (Gorgevic et al, WDI, 1993), 96% of the total area is affected by erosion. An area of 9,423 km^2 or 36.65% of the total state area is in the highest categories (Ⅰ – Ⅲ). The total annual erosion production for Macedonia is about 17,000,000 m^3 yr^{-1} or 680 m^3 km^{-2} yr^{-1}, with about 7,500,000 m^3 yr^{-1} or 303 m^3 km^{-2} yr^{-1} of sediment are moved away from the site where it is eroded. A significant part of these deposits within Macedonia, about 3,000,000 m^3 yr^{-1} is not carried through the downstream sections of the rivers to the exit of the state territory, but are deposited in natural lakes and reservoirs.

For example, the rates of annual sediment yield to the biggest reservoirs in Macedonia are: Tikves (1,300,000 m^3 yr^{-1} or 497 m^3 km^{-2} yr^{-1}), Kalimanci (420,000 m^3 yr^{-1} or 970 m^3 km^{-2} yr^{-1}). Typical for these reservoirs is that a great part of the eroded material was deposited in the so called "useful storage of the reservoir", decreasing water resources of the reservoir (Trendafilov et al, 2002).

Table 1 **Erosion distribution in Macedonia (by EPM methodology)**

Degradation category (erosion processess)		Area (km^2)	Percent (%)	Erosion intensity (m^3 km^{-2} yr^{-1})
Ⅰ	extremely high	698	2.77	>3,000
Ⅱ	high	1,832	7.38	1,500 – 3,000
Ⅲ	medium	6,893	27.78	1,000 – 1,500
Ⅳ	low	7,936	31.98	500 – 1,000
Ⅴ	very low	7,463	30.09	70 – 500
		25,713	100.00	

4.1.2 Erosion intensity in Serbia

The erosion map for Serbia was made in 1975 using EPM methodology. This map shows that, of the total area of Serbia, 86% is endangered by soil erosion of various rates. For the province of Vojvodina 72% of the area is endangered by soil erosion, and for the province of Kosovo and Metohija, 95% of the area is endangered. The new map of erosion produced in 2001 was little different than the map of 1975. Total annual erosion production in Serbia is 37,000,000 m^3 yr^{-1} or 422 m^3 km^{-2} yr^{-1} (Serbia- 488 m^3 km^{-2} yr^{-1}, Kosovo and Metohija- 249 m^3 km^{-2} yr^{-1}); annual sediment yield is 9,000,000 m^3 yr^{-1}, or 106 m^3 km^{-2} yr^{-1}.

In the normal erosion, which is a positive process, erosion intensity goes up to 100 m^3 km^{-2} yr^{-1}.

The most endangered region in Serbia is the southeast part of the country that is close to the Macedonia and Bulgaria borders.

4.1.3 Erosion intensity in Bulgaria

Data about Bulgaria is slightly different. While in Macedonia and Serbia was used EPM (methodology by Gavrilovic) and values are expressed in m^3 yr^{-1} or m^3 km^{-2} yr^{-1}, in Bulgaria is used USLE method for defining erosion intensity, i.e., erosion production (by EPM) or soil loss (by USLE) and values are expressed in t ha^{-1} yr^{-1}. It was assessed, that for 30% of the territory of Bulgaria, the potential erosion risk exceeds 40 t ha^{-1} yr^{-1}, and around 62% of the entire area, the risk is higher than 10 t ha^{-1} yr^{-1}. The estimated "actual" average annual soil loss rates vary from 0.14 t ha^{-1} yr^{-1} on forest lands to 2.7 t ha^{-1} yr^{-1} on pastureland and from 4.8 t ha^{-1} yr^{-1} on cropland to 12.7 t ha^{-1} yr^{-1} on vineyards, and orchards, resulting in the net average annual soil loss volume, estimated of 32,000,000 t (290 m^3 km^{-2} yr^{-1}), as over 2/3 of which originates from cropland (Lazarov et al., 2002; Rousseva et al., 2003). According to the National Long-term Erosion Control Programme (NLECP) estimations, the average annual soil losses at end of 70^{th} of the last century were 136,000,000 t (Biolchev et al., 1977). It would take into account that 68% of which was formed on the croplands, which represent 34.6% of the agricultural lands of Bulgaria at this period. The last study shows that the territory of Bulgaria represents 2.5% of the EU 27 countries area and contributes wiht 3.8% of the total soil erosion losses, estimated for that countries (Rousseva, 2012).

For the forestry fund the whole classified area at the end of year 2004, according to the degree of erosion, was about 292,000 ha which is 7.2% from the whole forest area (Marinov & Bardarov, 2005). It was found that the most widely affected by erosion were territories of the Regional Forestry Boards (RFB) – Blagoevgrad, Kardjali, Kiustendil, Sofia and Smolian. These areas vary between 30,000 and 60,000 ha. The distribution, according to the area affected to a different degree by erosion, as a percentage of the whole forest area of the respective forestry boards shows that the RFB Blagoevgrad, Kardjali, Kiustendil and Smolian have the highest percentage of territory affected by erosion-from 12% to 17%.

The methodological approach used in Serbia and Macedonia was also applied in Bulgaria, in particularly for the estimation of the sediment transport from the river Rakovitsa (747.5 ha), representative tributary for the middle part of the Struma river. It was established that the average total sediment transport (suspended and bed-load) using Poliakov-Kostadinov's method (Kostadinov, 1993) is 340 m^3 km^{-2} yr^{-1} (Marinov et al., 2005).

4.2 *Erosion control*

4.2.1 Erosion control in Macedonia

Few studies (Blinkov & Trendafilov, 2004, 2005, 2007; Blinkov et al., 2007), report for impressive positive results in this aspect.

Measures to control erosion were initiated in the early 1900's, aimed mostly at protecting rivers and reservoirs. Following passage of the Law on Financing Melioration Systems (1958), these measures were strengthened, and as of 1985, 285 torrents were regulated. The water management projections anticipate continuing this work.

Measures to control erosion on deforested barren lands have also been under way since 1945, when restrictions were placed on nomadic breeding of goats and sheep in forests. This measure, though unpopular, led to a recovery of degraded forest and shrub land.

There were few acts directly related to erosion control in the past: the Act for afforestation of bare land (1951), Act of erosion control on steep slopes (1952), and the Act of steep slopes protection and torrent control (1957). Later, these acts were suspended. As part of the erosion control programme an "Afforestation Fund" was established in 1970 and it existed until 1990.

Until 1990, erosion control measures and activities were on "higher level" and institutional support was higher. There were sections for erosion control in all regional water management enterprises. There were parts of the budget aimed at erosion control. Now, the situation is the opposite. Unfortunately, erosion is one the biggest environmental and economic problems in Macedonia, but there are no special funds available for erosion control.

In the period 1950's – 1970's, classical stone barrages were usually constructed. Then building of concrete barrages began. These structures were made by water management enterprises, where in past there existed a sector for erosion and torrent control. Now water management is in a transformation period. Plans are only partially completed. About 65% of planed hydraulic structures were built, but only 25% of planed afforestation occurred.

4.2.2 Erosion control in Serbia

The organized erosion and torrent control works (ETCW) in the territory of Serbia started prior to 1900 but the organized work began in 1907. The first works were for torrent control and channel training at the zones of intersections with railways, aiming at railroad protection.

There were works in the torrents of the Grdelička Klisura gorge in the South-East of Serbia, where the international railway line and road Belgrade-Skopje-Athens passes.

During the period of almost 100 years in Serbia the technology mostly applied were Classical European, French and Prof. Rosić's System of torrent control (Kostadinov, 2007).

In the field of erosion and torrent control in Serbia, especially after the Second World War (period 1946 – 1989) significant results have been achieved. Many roads and railways, settlements, industry, agricultural soil and storage reservoirs have been protected (fully or partially), from sedimentation and from torrent floods. Still, this is not enough, considering the present conditions and requirements. In the last 15 years there has been an intensification of erosion processes. For almost 100 years of ETCW in Serbia, it is characteristic that erosion control works were not performed on farmland on the slopes, except in the period 1955 – 1966 when there was a small effort to extend these works (Kostadinov, 2007).

4.2.3 Erosion control in Bulgaria

The erosion control activities on the territory of Bulgaria was started at the end of the 19^{th} century (1895) when the first erosion control plantations have been established (Stara Zagora, Kniazhevo, Dupnitsa, Kiustendil). The organized erosion and torrent control works started in 1905 when the first Section (Bureau) of torrent stabilisation and afforestation was created.

A significant amount of erosion control activities have been performed on the forest's territories and hydrographic network. A lot of studies (Kostov et al., 1995; Zakov & Marinov 2003; Rousseva et al., 2006; Panov, 2000; Zakov, 2005; NFB, 2005) report for impressive positive results in this aspect.

During the period 1905 – 1944 eroded lands, spread on the area of 170,000 ha have been afforested and 160,000 m^3 stone barrages (check dams) and thresholds (< 2.0 m above torrent bed) have been constructed. A National Long-term Erosion Control Programme (NLECP) was designed and implemented since 1982 (Biolchev et al., 1977). The NLECP made provisions for design of erosion control measures at a level of catchment, administrative territorial unit or the area of the co-operative farm. About 450,000 m^3 barrages and thresholds, 380,000 m^3 small stone thresholds and 350,000 m^2 wattles have been constructed during the period 1945 – 1989. This period is also remarkable for comprehensive afforestation of 1,900,000 ha of which 760,000 ha (about 40%) are anti-erosion forestation, and development of 20,000 ha shelterbelts (Zakov, 2005). In this period, the stabilisation of the torrents has been recognized as a substantial part of erosion control activities. More than 80 large complex erosion control projects have been designed and applied in the dam watersheds. The measures limited significantly the siltation of the dams. The coefficient of siltation, defined as a ratio between actual and predicted siltation, was low for nine of 15 dams studied and the deposition was within the range of acceptable values for two dams. There are a many successful stabilised torrential beds by biological measures in this period. An example is the bed of the torrential Perperek River, in the vicinity of Kardzhali, where a system of forest belts has been established. It was resulted in the retention of large amounts of sediments outside the dam Studen kladenets and provision of land suitable for forest and agricultural production.

The 1990s was characterized by a transition towards a market-oriented economy and land-property reform. Considering erosion control of the agricultural lands, the 1990's are marked as a decade of the complete carelessness. Permanent constructions to control erosion, once completed, have not been maintained after that, so their disintegration has been in progress. Many terraces have been damaged, collection ditches have been broken, grassed land has not been protected from excessive grazing (Rouseva et al., 2006). During the period 1989 – 2004 about 16,000 ha eroded lands has been afforested, 10,000 m^3 barrages and thresholds, 12,000 m^3 small stone thresholds and 7,000 m^2 wattles has been constructed (NFB, 2005). Some decrease of the afforestation works has taken place in the 1990s and especially since 1995, when the mean annual erosion control afforestation rate has been below 600 ha yr^{-1}. The erosion control hydro-technical construction works rate have been also decreased significantly while barrages of a volume about 1,000 m^3 yr^{-1} have been built (Zakov, & Marinov, 2003).

4.3 *Comparison of erosion intensity between countries*

Values for erosion intensity for Bulgaria are lower than those of Macedonia and Serbia, this may be a result of the methodology used (Table 2). USLE methodology only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses or erosion production that might occur from gully, wind even from weathering, landslides, landfalls.

Table 2 Erosion intensity per country

Country	Erosion intensity		Methodology
	$m^3\ yr^{-1}$	$m^3\ km^{-2}\ yr^{-1}$	
Macedonia	17, 000, 000	680	EPM
Serbia	37, 000, 000	422	EPM
Bulgaria	32, 000, 000	290	USLE

4.4 *Comparison of erosion control works between countries*

4.4.1 Quantity of erosion control works

Bulgaria has focused significant attention on afforestation of bare and other erosive land, with 950, 000 ha, Serbia and Macedonia follows with around 120, 000 ha afforested area (Table 3).

Table 3 Erosion control works for Macedonia, Serbia and Bulgaria

Country	Anti-erosion afforestation		Hydraulic structures on the forest fund	
	ha	% of the country territory	m^3	$m^3\ km^{-2}$
Macedonia	120, 000	4. 67	100, 000	3. 89
Serbia	120,987	1. 37	1, 501, 656	16. 99
Bulgaria	950, 000	8. 64	617, 000	5. 56

Regarding the afforested (with new forests for erosion control) territory (8. 6%) Bulgaria is one of the leaders in Europe. Macedonia paid significant attention to afforestation also. Percentage of afforested territory of the total country area is high also (4. 67%).

On the other hand, Serbia paid more attention on building of hydraulic structures in the torrent beds. The quantity of 16. 99 $m^3\ km^{-2}$ for hydraulic structures is among the highest in Europe.

4.4.2 Dynamics of erosion control works

A common characteristic for all three countries is that during the socialism period, there was a strong effort to control soil erosion. In the period after the fall of the old socialistic system, erosion control efforts decreased rapidly.

Afforestation in Macedonia was most intensive in the period 1975 – 1985. According to Fig. 3, afforestation rapidly decreased from 1985 to 1995. In the latest 5 years, afforestation has increase and the average intensity of afforestation in last 5 years (2005 – 2010) was about 5, 000 ha yr^{-1}.

There is no exact data available on hydraulic structures, but due to the collapse of and transformation of water management in the country, the trend of decrease continues.

For all three countries, the period from 1945 – 1990 was the "golden period" of erosion control works (see figures 3, 4, 5, 6, 7) when the intensity of implementing erosion control works are few times higher than in the other periods (before and after).

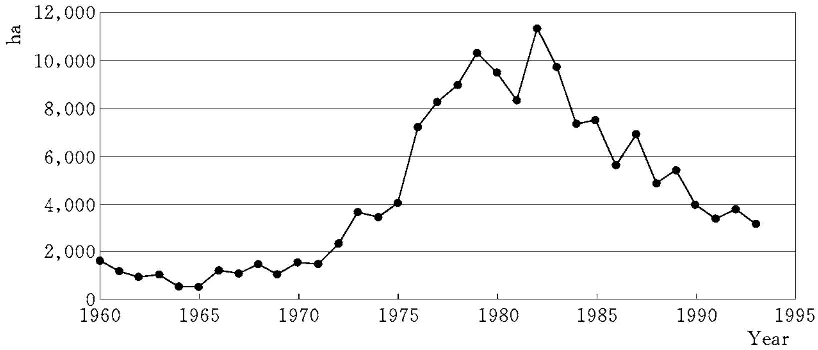


Fig. 3 Dynamics of afforestation in Macedonia 1960 – 1995

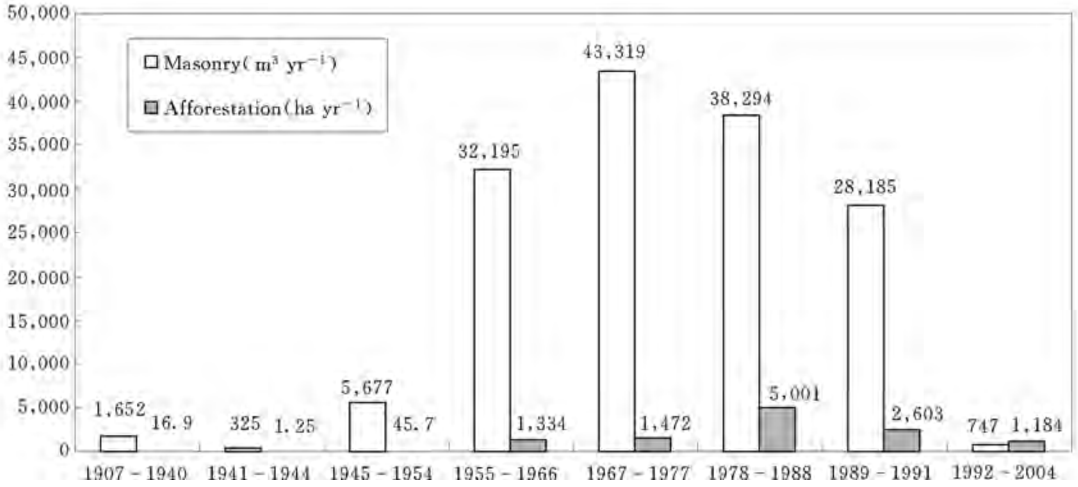


Fig. 4 Dynamic of erosion control works in Serbia

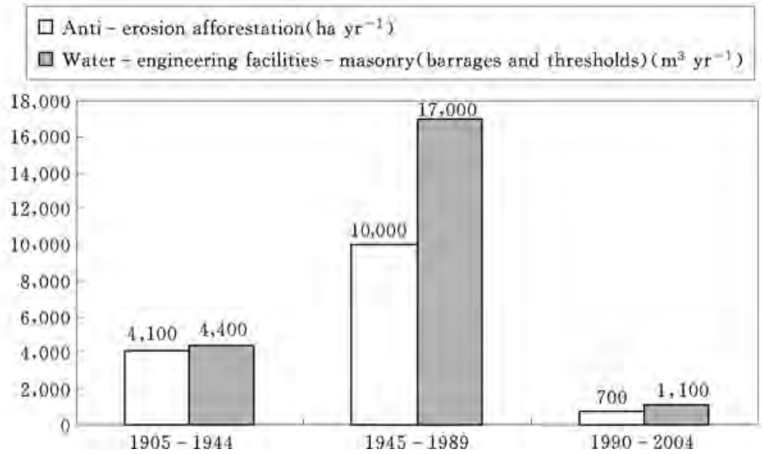


Fig. 5 Dynamic of erosion control activities in Bulgaria

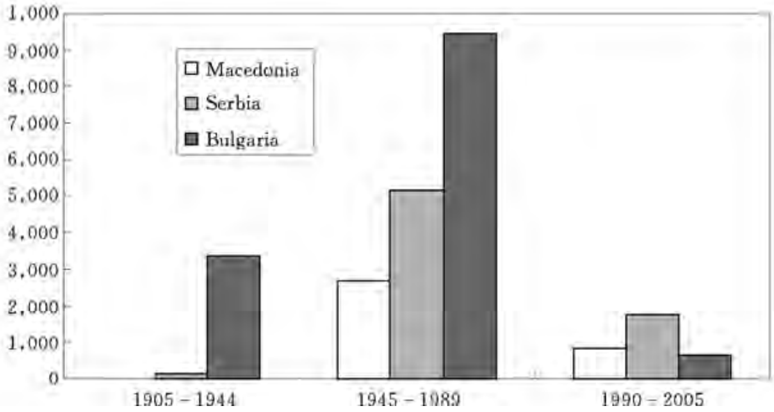


Fig. 6 Comparison of dynamic of annual intensity of anti-erosion afforestation

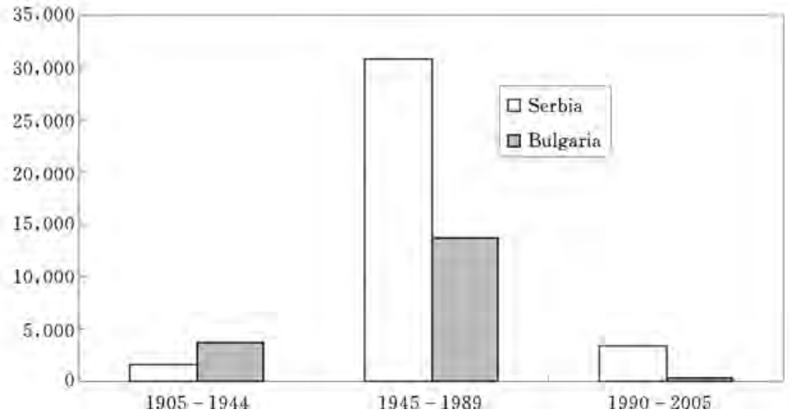


Fig. 7 Comparison of dynamic of annual intensity of building hydraulic structures

4.5 *Specific erosion control works*

Various erosion control works are done in all countries, but there are some specific works that are common to a particular country that are not common in the other two countries.

4.5.1 Specific erosion control works in Macedonia

The most specific hydraulic structure in Macedonia are screw check dams- Herheulidze type (Fig. 8). These structures are built in the western part of Macedonia where confirmation type is Alpine type. Erosion intensity is very high, weathering is significant and it results in rock particles with huge dimension. This type of check-dams was built in a few torrents in the western part of Macedonia.

Fig. 8 Screw check-dam (barrage) type Herheulidze (torrent Arvati and torrent Pena)

In the central part of Macedonia is a semiarid area where the total annual precipitation is less than 500 mm. The lowest measured annual precipitation in this area was 195 mm. This region is vulnerable to the desertification processes. Afforestation in this region was a challenge for various generations of experts. Various types of afforestation were carried out in this region using various tree species with aim to reduce erosion and greening of the area (see Fig. 9).

Fig. 9 Afforestation in arid region in Macedonia (plantation in holes and in furrows)

4.5.2 Specific erosion control works in Serbia

Erosion control experts in Serbia used various types of check dams but the most specific are Rosic-type: Filtration check dams (Kostadinov, 1995). Presented on Fig. 10.

Fig. 10 Specific check dams in Serbia-Rosic type

Serbia's biological works, besides classical afforestation, includes plantations of orchards on erosive land in the hilly mountainous region.

While in Bulgaria and Macedonia the greatest part of erosive land is state owned, in Serbia a significant part of the erosive land is private property. Private owners' interest is not only to protect land from erosion but to get an income from it. That was the main reason for orchard production on erosive land in the hilly mountain regions in Serbia (Kostadinov & Marković, 1996; see Fig. 11).

Fig. 11 Orchards on terraces in Serbia

4.5.3 Specific erosion control works in Bulgaria

While the new trend in stream restoration in Europe is "ecological stream restoration", it was carried out in Bulgaria long years ago. A typical example is the river Perperek where for the restoration only natural materials, wood and stone, were used. On Fig. 12 are presented photos from different periods (beginning of restoration and after a few decades). Now days this stream looks very natural. Bulgaria is one of the leaders in Europe in biological

Fig. 12 Regulation of river Perperek

works. In a region of Kardzhali a former "rocky desert" through intensive work was transformed into a good forest.

Another specific erosion control activities in Bulgaria are the using of the gabion thresholds which are built-up of separate horizontal parts of dry masonry stone encased in a metal net (Fig. 13). After the filled up of the thresholds and stabilized the sediments behind them, this terrain is forested.

Fig. 13 Gabion thresholds

5 Conclusions

Erosion intensity in Macedonia, Serbia and Bulgaria is among the highest in Europe, and erosion is assigned as one of the most important ecological and economic problems.

Faced with problems caused by soil erosion, organized erosion control began in the beginning of the 20th century.

The "golden period" of erosion control was the period of 1945 – 1990. After this period there has been a significant decrease of erosion control activities.

Serbia focused attention on building hydraulic structures. Intensity of 16.99 $m^3\ km^{-2}$ is among the highest in Europe. On the other hand, Bulgaria focused significant attention to anti-erosion afforestation – 950,000 ha and afforested 8.64% of the total area of the country, the highest in Europe.

Specific hydraulic structures are built in Macedonia-screw check-dams Herheulidze type. A specific practice for Macedonia is afforestation in extreme arid conditions.

Specific Rosic type check dams are characteristic in Serbia. Additionally, plantations of orchards on terraces in hilly mountain region are found in Serbia.

Beside mass afforestation, one of the most specific means of erosion control in Bulgaria is the "ecological river restoration" principle using natural materials: wood and stone. This has been a practice since about 1950. During the last few decades in Bulgaria for stabilizing of dry gullies the small gabion thresholds have been constructed.

References

Biolchev, A., Kitin, B., Kerenski, S., Ochev, N., Pimpirev, P., Stanev, I., ... & Tsvetkov, M. (1977). Methodology for Developing a National Long-term Erosion Control Programme in Bulgaria. Ministry of Agriculture. *Food Production and Forestry*, *Sofia* (in Bulgarian).

Blinkov, I., & Trendafilov, A. (2004). *Effects of erosion control works in some torrents in the Republic of Macedonia.* Conference on Water Observation and Information System for Decision Support, BALWOIS, 2004, Ohrid.

Blinkov, I., & Trendafilov, A. (2005, May). *Erosion control works in the Republic of Macedonia-country report.* International Conference "100 years erosion control in Bulgaria", Krdjali, Bulgaria.

Blinkov, I., Trendafilov, A., & Mincev, I. (2007, September). *Legislation and institution related to erosion and torrent control in the Republic of Macedonia*. International Conference "Erosion and torrent control as a factor in sustainable river basin managemen", Belgrade, Serbia.

Blinkov, I., & Kostadinov, S. (2010, May). *Applicability of various erosion risk assessment methods for engineering purposes*. BALWOIS conference, Ohrid, Macedonia.

EEA (European Environment Agency). (1995). *Europe's Environment: The Dobris Assessment An overview*, Editors: David Stanners and Philippe Bourdeau.

Gavrilović, S. (1972). Engineering of torrents and erosion. *Journal of Construction, Special Issue, Belgrade, Yugoslavia* (In Serbian).

Gorgevic M., Jelic D., Trendafilov A., & Gorgievsji S. (1993). WDI-Water Development Institute of Macedonia. 1993. Erosion Map of the Republic of Macedonia.

Gobin, A., Govers, G., Jones, R., Kirkby, M., & Kosmas, C. (2003). Assessment and reporting on soil erosion. Background and workshop report. http://eusoils. jrc. ec. europa. eu/esdb_archive/pesera/pesera_cd/pdf/ TechRepSoilerosFIN110902. pdf.

Kostadinov, S. (1993). Mogućnost merenja i prognoze pronosa nanosa u bujičnim tokovima. Monografija: "Uzroci i posledice erozije zemljišta I mogućnosti kontrole erozionih procesa". Izdavač: Šumarski fakultet, Beograd, 58 – 67 (in Serbian).

Kostadinov, S. (1995). Analysis of the Effects of Classical and Filtration Check Dams in the Torrents of Serbia. In *Proceedings of the XXVI IECA Conference*, Feb. 28th - March 3rd, 1995, Atlanta, 111 – 124.

Kostadinov, S., & Markovic, S. (1996). Soil erosion and effects of erosion control works in the torrential drainage basins of southeast Serbia. In *Erosion and Sediment Yield: Global and Regional Perspectives (Proceedings of the Exeter Symposium, July)*. IAHS Publ., 236, 321 – 332.

Kostadinov, S. (2007, September). Erosion and torrent control in Serbia: hundred years of experiences. In *International conference "Erosion and torrent control as a factor in sustainable river basin management", Belgrade* (pp. 25 – 27).

Kostov, I., Zakov, D., & Marinov, I. Ts. (1995). Ninety years organised activities for erosion control in the forest fund in Bulgaria. In I. Ts. Marinov (Eds) *Scientific Conference with Participation of Foreign Specialists* "90 *Years of Soil Erosion Control in Bulgaria*" (pp. 3 – 7). Sofia: Lotus Publishers.

Lazarov, A., Rousseva, S., Stefanova, V., Tsvetkova, E., & Malinov, I. (2002). Geographic Database and Evaluation of Different Soil Erosion Prediction Models for the Purposes of the Soil Information System. Final report of Research Project Contract No. 1108 – 2556. Ministry of Environment and Water: Sofia.

Marinov, I. T., Kostadinov, S., & Lubenov, T. (2005). Calculation of sediment transport in Rakovitsa torrent watershed. *Silva Balcanica*, 6(1), 5 – 15.

Marinov, I., & Bardarov, D. (2005). Erosion state of the soils in the forestlands. *Forest science*, 4, 69 – 78.

Morgan, R. P. C. (1992, May). *Soil Erosion in the Northern Countries of the European Community*. EIW Workshop: Elaboration of a Framework of a Code of Good Agricultural Practices, May 21 – 22, Brussels (cited by Monatanrela L., The EU Thematic Strategy on Soil Protection).

National Forestry Board (NFB). (2005, May). *Soil erosion in Bulgaria-state and measures, National report*. International Conference "100 years erosion control in Bulgaria", May 18 – 21, Kardzhali, Bulgaria (in Bulgarian).

ÖzyuvacÚ, N., Özhan, S., & GörcelioXlu, E. *Integrated watershed management for sustainable development of renewable natural resources* (pp. 263). Retrieved from http://www. fao. org/forestry/docrep/wfcxi/PUBLI/PDF/V2E_T9. PDF (Accessed on 22 April, 2011).

Oldeman, L. R., Hakkeling, R. T. A., & Sombroek, W. G. (1991). *World Map of the Status of Human-Induced Soil Degradation, with Explanatory Note (second revised edition)*. ISRIC, Wageningen; UNEP, Nairobi (cited by Monatanrela L., The EU Thematic Strategy on Soil Protection). Retrieved from http://eusoils. jrc. ec. europa. eu/events/SummerSchool_2003/presentations/III_SoilFunctions/PT01SoilProtStrat_LM. doc. pdf.

Panov, P. (2000). *The tamed torrents in Bulgaria*. Publishing house of the National Forestry Board at the Ministry of Agriculture and Forest (in Bulgarian).

Petkovic, S., Dragovic, N., & Markovic, S. (1999). Erosion and sedimentation problems in Serbia. Hydrological sciences journal, 44 (1), 63 – 77.

Rousseva, S., Lazarov, A., Tsvetkova, E., Marinov, I., Malinov, I., Krumov, V., & Stefanova, V. (2006). Soil erosion in Bulgaria. In J. Boardman and J. Poesen (Eds), *Soil Erosion in Europe* (pp. 167 – 181). London: John Wiley Ltd.

Rousseva, S. (2012). Factors and rates of soil erosion in the Balkan Peninsula. In Christov, I. (Ed.), *Proceedings of International Conference "Ecology-Interdisciplinary Science and Practice"* (Part One, 43 – 47). Sofia 25 – 26 Oct. 2012.

Rousseva, S. , Lazarov, A. , Stefanova, V. , & Malinov, I. (2008, May). *Soil Erosion Risk Assessments in Bulgaria*. BALWOIS conference, May 25 – 29. Ohrid, Macedonia.

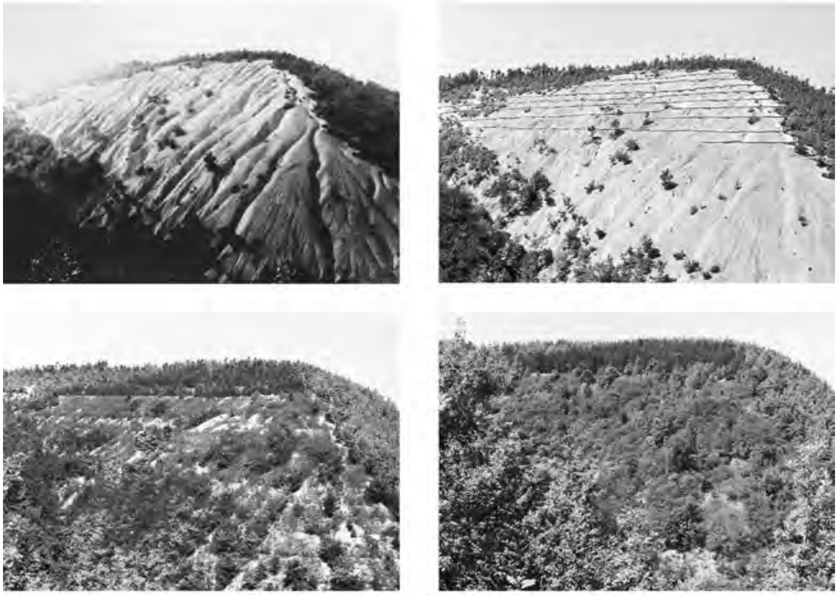
Rousseva, S. , Banov, M. , & Kolev, N. (2003). Some Aspects of the Present Status of Land Degradation in Bulgaria. In Johnes, R. & Montanarella, L. (Eds), *The JRC Enlargement Action*, *Workshop* 10-*B*, *Land Degradation* (pp. 149 – 164). EC-JRC.

Zakov, D. , & Marinov, I. (2003). Erosion and torrent control in Bulgaria. In Zlatić, M. , Kostadinov, S. , Dragović, N. (Eds.), *Natural and Socio-Economic Effects of Erosion Control in Mountainous Regions* (pp. 525 – 530). Finegraf, Nikole Marakovića bb: Belgrade.

Zakov, D. (2005). 100 *years of erosion control in Bulgaria*. Sofia. 104.

ANNEX—Effects of anti-erosion afforestation

Serbia



1958 – 2005

Serbia

1958

2003

Bulgaria

1955

2005